NEMO: Need-inspired Emotional Expressions within a Task-independent Framework

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Abstract This paper presents the underlying algorithms of an emotion model within a task-independent framework. This model, called NEMO is a task independent model that integrates a module of needs for emotional expressions. We suggest that appraisals can be confined within various scopes of needs. In other words, the emotion framework allows control over appraisals based on a set of pre-defined levels of needs. This way, the agent is able to sort out his priorities, and express emotions according to his needs. The definitions of the needs and appraisals concepts along with their computations are presented to demonstrate their relations with the emotion generation mechanism in a multi-tasking environment of an autonomous emotive agent.

1 Introduction

Psychologists agree that underlying the two main concepts of emotional phenomena in agents based on the perspective of human emotion; person-environment relationship (appraisal) [6] and coping [13, 7], is motivation, the central concept [10], that is the driving force that guides the agents behaviour. In biological systems, motivations are concerned with internal needs related to survival [2] and psychological needs related to self-sufficiency. Motivation varies as a function of deprivation in a form of varying internal states, and the latter are postulated to explain the variability of behavioral responses [2]. But what is the relation between motivations and emotions? Tomkins [14] (p.164) views emotions as the primary motivating mechanism. According to him, the affect system adds strength to drives as motives

> ...without its amplification, nothing else matters, and with its amplification, anything else can matter. It thus combines urgency and generality...

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In another similar view, Zimmerman [15] pointed out that the deficiencies of the various levels of need are actually experienced emotionally on a conscious level, but the individual may be unconscious regarding the level of need he or she is deficient of. In his words (p.3),

> The deficiency in safety needs is experienced as fear by many people. When safety needs are met, fear disappears. As Maslow [9] has pointed out, when a need is satisfied, a new higher need emerges. In this case we might see the love needs arise in which one needs to be courageous. In this sense, fear is replaced by courage.

Thus, he coined the word ”need-emotions” to relate need deficiencies as experiential emotions. These theories served as inspiration to incorporate a need module in our affect model for a domain-independent multi-tasking agent, called NEMO (Need-inspired Emotional Model). To demonstrate this, we propose an emotion framework which allows control over appraisals via pre-defined levels of needs, urgency or priorities. In other words, appraisal components derive information from the need components, implicitly computed, which results to the elicitation of a suitable emotion response, represented in the agents behaviour. Any changes in appraisals are dependent on the need level, which underlies the reasoning techniques that support the frameworks cognitive process. The motivation framework is based on literature by Abraham Maslow [9], describing a renowned motivational hierarchy explaining human needs from the most basic to reaching self-actualization. According to Maslow, human beings first gratify the most basic needs, before they are motivated to move on to the next level, thus, each level takes precedence over others. In NEMO, the original Maslow model has been recasted to the agents conceptual view (refer pyramid in Figure 1).

What makes our approach different from other appraisal-based approaches is the addition of the need layers that function as a decomposer of task-specific events according to their importance and urgency.

This paper focuses on the descriptions and algorithms underlying the needs and appraisals for emotion generation. It is organized as follows: Section 2 presents a brief description of the model architecture and process flow. Section 3 and 4 further details the algorithms to generate need values and appraisal vectors based on the conceptual view of this model. Simulation results are presented in the Section 5 and finally, the last section discusses and concludes the findings of the simulation results and the advantages of the model.

2 A Need-Cognitive-Affective Task-independent Model

The objective of this study is to develop an adaptive, task-independent domotic agent. At such, the agent integrates various domestic appliances that could perform different tasks. In view of this objective, a scalable architecture is built based on task. In NEMOs architecture (Figure1), the agents interpretation of his relationship with the environment is realized explicitly in the representations of the appraisal variables filtered by needs. This representation encodes the input, and outputs the reasoning process that mediate between the agents goals in achieving his tasks and his physical environment. Each task provides an input that has relation with certain need levels (e.g.: staying alive is considered a task that is related to the physiological need-level). Task based events provoke variations in needs. In other words, these events are *inputs* that affect various need 'satisfaction' in the scope of the Maslow pyramid, producing varying *need values* (termed M-values). As events change quickly, M-values vary on the same rhythm, also taking into consideration the values on *previous state* producing dynamicity. In the process of satisfying his needs, the agent appraises his situation (e.g.: determining task priorities etc.), taking the M-values as input. Needs are appraised using several appraisal variables (Desirability, Unexpectedness etc.). Appraised needs are output as vectors, called the Need Independent Feature (NIF). Each NIF vector is mapped into an *emotion instance* of a specific type and intensity following an Emotion Matrix. To account for the prioritization of need (which indirectly projects the importance and urgency of a task), a constant-weight is added to each instance, depending on the need-level (lower level with greater weight). Finally, the dominating emotion obtained affects both the cognitive process and behaviorselection of the agent similar to the conducts of humans. A much detailed explanation of the architecture is given elsewhere [5].

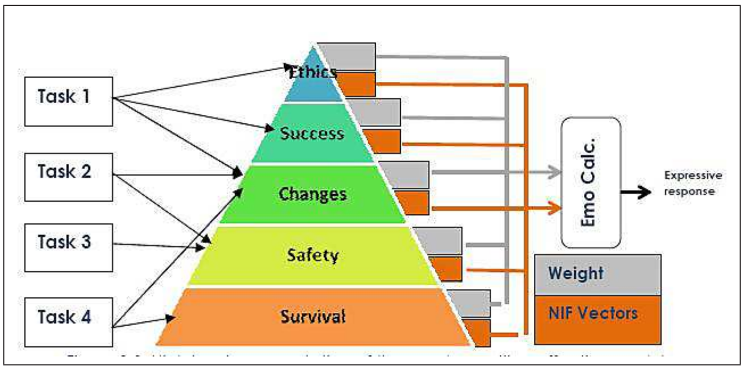

Fig. 1: High level architecture of the need-cognitive-affective model.

3 Definitions and Algorithms for Needs and Appraisals

In realizing the theoretical framework of needs and appraisals, need levels and a subset of appraisals are modeled with simple rules. This section presents the rules for variation of need-satisfaction (to compute M-values) and Need Independent Features (NIF) or appraisals. Though the rules for needs are bound to change, depending on the engineers perspective of needs, the rules for appraisals are fixed and straightforward, due to the transparency in their functions. This section describes the rules for both needs and appraisals.

3.1 Needs

The computations of needs are in the form of M-values and the general rules are:

- The M-values are scaled from 0 to 100, where 0 indicates the least satisfied need and 100 indicates the most satisfied.
- Any event that produces a critical M-value close or below 15 indicates an urgent (critical) situation.

3.1.1 Survival

In this level, computation is straightforward, since Survival depends directly on the critical components of the operation system. The failure of satisfying this need would put the whole system to a halt. The components that are considered in this level are the available memory, available disk space, external and internal battery status and performance speed (a feature provided by Windows ™). All of these components should maintain a reasonable value. If any of these components fall short, the survival level decreases. For example, if the battery level is at its maximum, but free memory is restricted, survival rate will turn out low. Computation of Survival is:

$$Survival = 100 \times availableMemory \times availableDisk \times \\ performanceSpeed \times externalBatteryStatus \times internalBatteryStatus \quad (1)$$

3.1.2 Safety

Safety is programmed to be directly dependent on the availability of network. If the network is not available for more than 10 seconds, safety level decreases. Computation for safety takes place in every 100 miliseconds.

3.1.3 Changes

Changes are linked to general activities being performed using different modules or general interactions between the agent and users. If there are general interactions with the agent, or if there are tasks being carried out, the agent interprets his social environment as being active, and so his satisfaction rate for changes-need increases.

3.1.4 Success

The Success level is influenced by various events related to different modules. Success rate is measured by determining the opposed factor. This is done by updating a predefined value in percentage of the individual event (values differ according to events). For an example, a facial caressing event may have a fixed value of 0.5, indicating a medium success level, winning a game fixed with a 0.7 a high success level, accurately detecting speech fixed with a 0.6 etc., to compute the corresponding *opposed* M-value. If there is an increase in percentage, the opposed M-value decreases whilst a decrease in percentage indicates an increase in the opposed M-value. At such, a logical evolution of need gratification could be seen depending on events that occur at different satisfaction level of success-need. In other words, positive or negative events have different significance depending on the *state of the satisfaction level*. Positive events are less significant when the agent's state of success satisfaction level is high; therefore these events only cause minor modifications to the success rate. On the other hand, if the agent's state of satisfaction is low, the same positive events may have a significant impact on his satisfaction level. The computation for Success level is:

$$Opposed = 100 - (success_{previous}) \tag{2}$$

Once the 'opposed' value of the first even is determined (2), success value for the current event can be computed:

$$Opposed - value = \left(1 - percentage_{successfulEvent}\right) \times (\ 2) \tag{3}$$

$$Success_{current} = 100 - (\ 3) \tag{4}$$

As opposed, a failure (unsuccessful) value is calculated as:

$$Success = \left(1 - percentage_{failureEvent}\right) \times (\ 4) \tag{5}$$

Note that the failure events are calculated in terms of success (very low success indicate failure). Therefore the success value in (5) would be much lower than in (4).

3.1.5 Ethics

Ethics level is affected particularly by events of two types of tasks which are Playing Game and Detecting Speech; legal or illegal movements are related to the former while praise, insults or threats that the agent has detected are related to the latter. The computation of Ethics need satisfaction is similar to the Success need. Illegal movement in a game, insults and threats would increase the opposed level, whilst legal movements and praises would increase the ethics satisfaction level.

3.2 Need Independent Features (NIFs a.k.a. Appraisal Variables)

Several subsets of appraisals were chosen (Table 1) guided by ideas shed in modeling the domain-independent emotion model EMA [8]. Here, the behaviors of the NIFs (appraisal variables) are described at a high level, followed by the listing of the computational rules.

Table 1: Summary of NIFs

Appraisals	**Descriptions**
Desireability	The positivity or negativity of an event with regards of the agent's need
Unexpectedness	Was the event foreseen based on its occurrence in the recent past?
Relevance	The degree of the significance of an event
Urgency	The time estimated before reaching a critical condition
Controllability	Is the event under control?
Unfamiliarity	The degree of acquaintance with a change of event based on past knowledge
Changeability	The range of need variations along time axis

The computation of NIF is based on task-specific and general events that are grouped within one or more need levels. At such, the agent appraises his needs based on the past and present knowledge in the form of M-values. In other words, the M-values are the input for the computation of the NIFs.

3.2.1 Desirability

Desirability encodes the valence of an event with regard to the agents needs. An event is deemed desirable if it contributes in satisfying the agents needs, or if it restrains a situation that thwarts the agent from satisfying his needs. An event is undesirable if it attributes to difficulties for the agent to achieve his needs, or if it inhibits a positive situation that encourages the agent in achieving satisfaction of needs. According to Gratch and Marsella [4], desirability plays a double role in appraising a certain situation, in the sense that it distinguishes emotions clearly (Happiness from Sadness; Hope from Fear) and arouses the degree of a particular emotion (intensity variable). In this proposed system, one is able to view the intensity level of an emotion is reflected based on the process of need achievement (in simulation graphs). However, it is not encoded in the agents behavior due to the limitations of facial or vocal emotion elicitation reflecting intensity. In NEMO, desirability is modeled by observing the current and previous events:

$$Desirability_n = Mval_n - Mval_{n-1} \tag{6}$$

where $Mval_n$ is the M-value of the current state and $Mval_{n-1}$ the M-value of the previous state, henceforth.

3.2.2 Unexpectedness

Unexpectedness accounts for whether an event violates one's expectation. Roseman [11] suggests that an emotion system should use the 'unexpectedness' variable to produce surprise, as opposed to other positive or negative emotional responses. If an event is unexpected, a person may behave

> erroneously or inappropriately (pp.77)

and the situation of unexpectedness is used to suspend his or her current action in order to gain understanding of the situation. Thus, unexpectedness is viewed as an adaptive response strategy - the time needed before surprise is gradually converted to other negative or positive emotion.

The agent perceives unexpectedness when he does not foresee an event or when he wrongly predicts an event based on his experience in the recent past. In NEMO, recent past confines the events of a defined duration of time, viewed as:

$$Unexpectedness_n = \frac{\mid (Mval_n - Mval_{n-1}) - (Mval_{n-1} - Mval_{n-2}) \mid}{2} \quad (7)$$

where $Mval_{n-2}$ is two previous states, henceforth.

3.2.3 Relevance

Relevance measures the importance or significance of an event. In NEMO, relevance is related to the degree of need satisfaction. It is equated with low or high MValues. An event outcome is perceived as significant if it inhibits the agent from satisfying his needs or when the M-value is observed as very low (close or below a critical zone). As Gratch [4] points out, virtually every event has some sort of significance. To realize this, the model is equipped with a non-zero utility so that when the need satisfaction is at its maximum, the event outcome will not be perceived as completely irrelevant. Therefore the model for Relevance is:

$$Relevance_n = \frac{100 \times (100 - levelAux)}{100 - CriticalValue} \quad (8)$$

Where, levelAux is the most relevant modification (set to changes of Mval at minimum of 5 units, changes that is lower than 5 units are considered not important and thus will not influence the current emotion process) and $CriticalValue \leq 15$, henceforth.

3.2.4 Urgency

The urgency considers the distance between the current state of the need and the critical level. In other words, the time available before reaching a critical situation.

A situation is deemed urgent when the distance between the state of the need and the critical zone is narrow or when it reaches the critical level (in the computation, when it reaches a zero or negative utility). A situation is perceived as not so urgent if there is a reasonable distance between the state of the need and the critical zone. The speed of the change of need variation (current state as opposed to previous state of need) towards the critical value also plays an important role in determining urgency. In NEMO, the suitable behavioural response provoked by urgency is fear, consistent with the hypothesized appraisal pattern shown in [12]. Therefore the computation for urgency is:

$$\begin{aligned} If\,\mathrm{Mval}_n \leq CriticalValue, &\quad Urgency = 100; \\ ElseIf\,\mathrm{Mval}_n + (Mval_n - Mval_{n-1}) \leq CriticalValue, &\quad Urgency = 100; \\ Else\,Urgency = \\ (100-\mathrm{Mval}_n) \times 0.005 \times (100 - (Mval_{n-1} - Mval_n)) \end{aligned} \tag{9}$$

3.2.5 Controbility

Controllability does not directly depend on the Mvalues. Whether or not an event is controllable depends on the task. Events that are considered controllable are positive, while events that are uncontrollable are negative. The system periodically computes this by comparing the positive or the negative events against all actions.

3.2.6 Unfamiliarity

Unfamiliarity measures how ”new” an event is. If the difference in changes of several events over time is exactly the same, the agent becomes increasingly familiar with the event. After a number of sufficient repetitions, the unfamiliarity level reaches a zero-utility (as opposed to being highly familiar with the particular change of event). On the other hand, if there is a new change of events that never took place before, the situation is considered unfamiliar. The computation of Unfamiliarity employs the Mahalanobis distance [1]. The distance of Mvalue variations from its mean is taken and divided by its standard deviation. The further the distance, the higher the unfamiliarity, and vice versa. Each time a change of event occurs, the mean and the standard deviation of the frequency of event-occurrence is updated:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(changes_i)^2}{totalEvent} - \mu^2} \tag{10}$$

$$\mu = \frac{\sum_{i=1}^{n}(changes_i)}{totalEvent} - \mu^2 \tag{11}$$

where $changes_n = Mval_n - Mval_{n-1}$

The Mahalanobis distance is applied in this domain:

$$If\sigma > 0, \quad Unfamiliarity_n = 100 \times \frac{|Mval_n - \mu|}{|4.0 \times \sigma|} \tag{12}$$

$$Else\, Unfamiliarity_n = 100 \times |Mval_n - \mu| \tag{13}$$

Note that equation (13) demonstrates that the futher the current Mval is from the mean μ, the higher the unfamiliarity will be.

3.2.7 Changeability

Changeability is related to the range of the need variation along time axis. As estimation, $4.0 \times \sigma$ is chosen. The wider the range of the need variation, the higher the changeability.

4 Emotion Generation

As described in the algorithms above, the updates of M-values generate the corresponding NIF vectors that become the input for the computation of emotion and its dynamics. Appraised needs are output as vectors, whereby each vector is mapped into an *emotion instance* of a specific type and intensity, following an Emotion Matrix.[1] To account for the prioritization of need (which indirectly projects the importance and urgency of a task), a constant-weight is added to each instance, depending on the need-level (lower level with greater weight). Finally, the dominating emotion obtained effects both the cognitive process and behavior-selection of the agent - similar to the conducts of humans. Our current model illustrates six types of emotions (Figure 2) - Happiness, Sadness, Surprise, Anger, Fear and Neutral.[2] These emotions are elicited via two modalities, speech and/or facial.

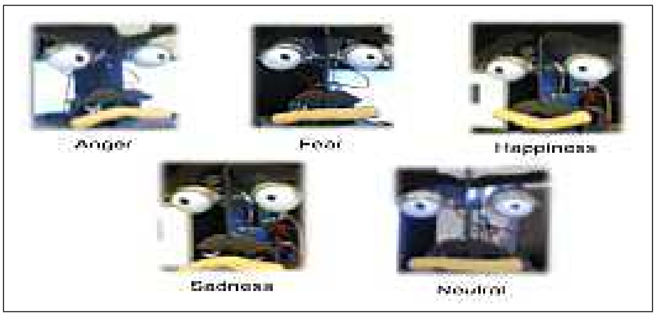

Fig. 2: Facial expressions of the agent. *Surprise* facial response is not included as to date, it is not finalised.

[1] Due to limited space, iti s not possible to include the computation formulas for emotion generation and the emotion matrix

[2] If M-values are not updated for some time, the emotion level surpresses, and finally reaches a neutral level

5 Simulation Results

This section presents some simulation results for three levels of need; Survival, and Ethics. The charts below show the related appraisal dynamics that are influenced by the agent's need satisfactions (in the form of M-values).

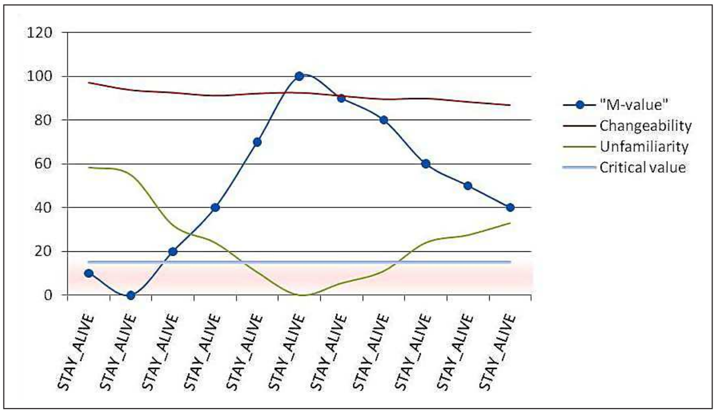

Fig. 3: Simulations for Unfamiliarity and Changeability within the Survival level.

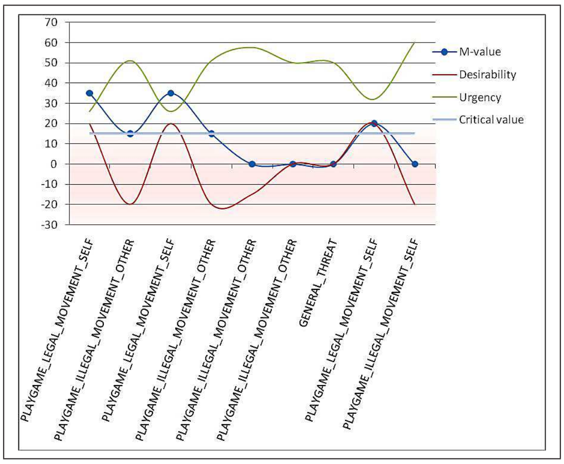

Fig. 4: Simulations for Desireability and Urgency within the Ethics level.

The results obtained in the simulations are expected. In Figure 3, as the vital components (battery, memory etc.) for staying alive increases and then decreases consistently (illustrated by M-value), changeability is also consistent. Thus the agents

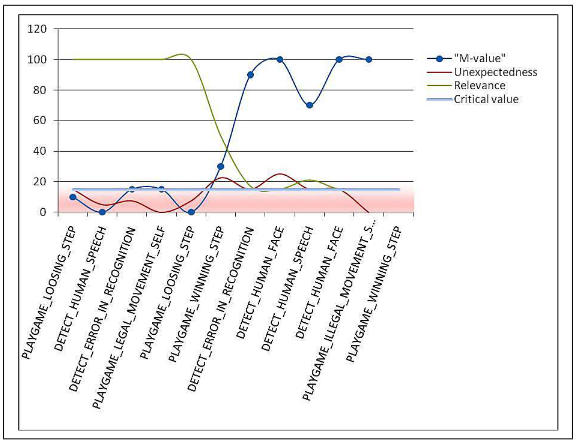

Fig. 5: Simulations of Unexpectedness and Relevance within the Success levels

unfamiliarity appraisal stays low, projecting a positive emotion. Figure 4 shows that in Ethics level, many undesireable events took place, projecting a negative emotion such as anger or sadness. Also, when M-values are below critical level, an urgent situation emerges, causing a possibility of fear. Figure 5 illustrates Unexpectedness and Relevance in the Success level. When the agents satisfaction shows a sharp increase, unexpectedness also increases, provoking Surprise. On the other hand, critical events put the situation at maximum relevance.

6 Discussions and Conclusions

The model offers several advantages ; First, *task independency*. As explained earlier in Section 2, the agent's causal interpretation is influenced by his needs. Technically, the agent's interpretation is based on the *Maslow variation (M-values)* which is in turn modified by these events. He does not directly analyze the internal operations of each task. Thus, the behavior of the agent is *independent* of the existing task(s). The agent is appraising his needs rather than the tasks and its situations. Secondly, in this way, this module preserves the scalability of tasks, whereby the agent's tasks can be added or appropriately changed to suit applications in different domains. The next phase would be to transfer the simulation experiment onto a partially developed system for further investigations. Other nearest future effort involves collaboration with a previous study [3] in a spoken dialogue system for controlling a Hifi audio system. The study has comprehensive findings on user-satisfaction based on series of evaluations with real users. The user satisfaction is correlated to several features such as efficiency of turns, dialogue contextuality, system request etc. This available data could be used to predict the agent's behaviour by modeling the agent's needs accordingly; in such ways that those needs correlate to the satisfaction results of the previous evaluations (with real users) from the study. It is also hoped to include a Culture model into the existing framework.

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